10 LISTENING GAMES

User's Guide

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◁10 Listening Games

This CD-ROM consists of educational games created and developed within the context of Ircam's workshops. They were essayed at length with both children and adolescents in order to achieve a balance between play and study, and to develop informed mechanisms for listening, memorizing and recognizing.

While the pedagogical tools are fairly standard — quizzes, puzzles, classifications, etc. — the originality of the approach lies particularly in the quality and relevance of the musical material

offered, borrowed variously from art music, popular music and sound effects.

Thanks to tools developed at Ircam in music research, you will find gradual progressions, paradoxes and precision spatialization. The games have three levels, the most challenging of which can be fairly subtle. . . .

_ musiques tangibles

10 Listening Games is the second CD-ROM in the **musiques tangibles** collection, which consolidates *hyptique.net*'s titles in the musical domain, bringing the most varied fields of contemporary music creation to a wider public, both amateur and professional.

_ hyptique.net

hyptique.net's intention is to promote interactive creation.

"Interactivity is a new form of expression? The aesthetic arising from it, while inscribed in our artistic tradition, asks new questions, and acts decisively on the evolution —not to say mutation — of the surrounding cultural discourse. Our goal is to reveal this change and to display its logic."

– Pierre Lavoie

_ Introduction

10 Listening Games is the result of several years of educational experience with Ircam's youth workshops. A musical theory of sounds, it's geared to training the ear for a more refined and nuanced perception of auditory phenomena. The user learns listening, recognition, memorization and the manipulation of specific characteristics of acoustic and electronic sounds. Timbre, auditory space, morphing and fragmentation are the subjects of the exercises, rather than the objects of traditional solfege, such as pitch and rhythm. The CD-ROM has 10 exercises, most of which have three levels of difficulty. Classifying and combining are the two underlying pedagogical principles. Thus, for every exercise, the user explores a particular sound quality, progressively refining it through a process of listening and evaluation. With the automatic correction feature, users can assess their progress at different stages of their work.

For Whom Is This CD-ROM Intended?

This CD-ROM, for both learning and play, is for children 8 years old and up. It is designed to be used in two ways: individually, with the help of the internal guide; or in a group, accompanied by a teacher or a presenter.

What's on this CD-ROM?

The CD-ROM presents 10 exercises, organized as follows:

Identifying sounds, 3 exercises

Classifying Sounds: classify sounds by timbre (3 levels).

Graphic Representation of sound: match sounds with images (frequency spectrum and amplitude envelopes) (3 levels).

Identifying Sound Events: match the sounds to the appropriate descriptive terms (3 levels).

Organizing sounds, 3 exercises

Sound Morphing: reconstruct a gradual transition between two timbres (3 levels).

Musical Theme Morphing: reconstruct a gradual transition between two musical themes (3 levels)

Music Puzzle: rebuild a music sequence from its fragments (3 levels)

Placing sounds in space, 3 exercises

Acoustic Spaces: classify sounds by their reverberations (3 levels)

Locating a Sound Source: classify sounds spatially (right, left, in front, behind) (3 levels).

Sound Sources in Motion: classify sounds by their movements (from left to right, from in front to behind, etc.) (3 levels)

Relating sound and image, 1 exercise

Synchronizing Sound and Image: match a visual animation with a sound sequence (1 level).

How was this CD-ROM produced?

This CD-ROM was produced by Ircam's Pedagogy Department.

Ircam (*Institut de recherche et coordination acoustique/musique*) combines scientific research labs with music creation studios. The ensuing continual dialogue between researchers and designers constitutes the originality and the richness of the Institute. One of the most fertile areas of this interaction is the development of composition software. Sound synthesis, computer-assisted composition, and musician-computer interactivity are three domains in which Ircam has made significant contributions since its founding.

The mission of the Pedagogy Department is to train composers, researchers, technicians, teachers, students and schoolchildren in computer music, relying mainly on the music creation programs developed at Ircam.

These programs have enabled us to design the 10 exercises which make up this CD-ROM. They have been tested and improved in numerous youth education workshops.

User's Guide

The guide provides information on several levels.
First:

- a description of the general mechanics for handling the CD-ROM (**Using the CD-ROM**).

For each exercise:

- a statement of the goal of the exercise (**Objective**) and how to proceed, together with explanations of the underlying ideas (**Performing the Exercise**);
- suggestions for learning enhancement through a related activity (**Educator's Tips**).

For some of the exercises, a didactic supplement for technical subjects (**Going Further**).

And also:

- help for installing the CD-ROM (**Installing the CD-ROM**)

Using the CD-ROM

❖ Starting the program

If Quicktime 3 (or higher) is already installed on your computer, you can start the application by double-clicking on the file "démarrage" for Macs or the “start.exe” file for PCs.

The page "Exercises" appears after a brief introduction.

❖ Various Elements of the CD-ROM

Tabs found at the bottom of the screen control access to various aspects of the CD-ROM.

♦ "Exercises" Screen: if you have just opened the application, this screen is already active. If you are in another part of the CD-ROM, click on the menu tab "Exercices" at the bottom of the screen.

The screen displays a series of doors, each door corresponding to an exercise. As the mouse is positioned over each of the doors, the name of the exercise and its icon are displayed at the top of the screen. To open an exercise, click on one of the doors.

The level of difficulty appears in the upper right. To change the level of difficulty, click on the desired level (1, 2 or 3) on the left side of the screen.

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To open the “Mode d’emploi,” which describes the underlying working principles of the exercises, click on the blue door on the left of the screen.

♦ "Guide d'utilisation" (User's Guide): to go to this feature of the CD-ROM, click on the tab "Guide d'utilisation" found in the menu on the bottom of the screen. Thereafter, to access an exercise-specific user's guide, click on the exercise name in the list displayed on-screen.

♦ "Credits" screen: click on the “Credits” tab to consult the list of people who contributed to making this CD-ROM.

♦ Quitting: click on the tab "Quitter" to quit the application.

❖ Useful Techniques for the Exercises

- Playing a sound: double-click on these icons. A “double-click” is produced by pressing the mouse button twice in rapid succession. The speed of the double-click is a parameter you can set in MacOS (control panel / mouse) and in Windows (configuration panel / mouse). Just click on the sound to stop it from playing.

- Moving a sound: often the sound icons must be moved around the workspace, for which you use the "drag and drop" technique. To bring (or "drag") the icon representing the sound to its desired place, click on the image you want to move, and hold down the mouse button while moving the mouse. Release the mouse button only when the icon is where you want it placed (this is the "drop").

❖ User Interface in the Exercises

All of the exercises have the same interface displayed at the bottom of the screen.

- Opening the user's guide from an exercise: click on the button "Guide d'utilisation" at the bottom right of the screen to open help for the exercise underway.

- Volume control: during any exercise, you can regulate the sound level. Move the mouse so that the cursor is on the bottom left of the screen. A fader will appear under the cursor. Moving it up or down raises or lowers the volume.

- Levels of difficulty: the level of difficulty for the exercise that’s open is displayed in a small box on the right side of the screen.

- Quitting the exercise: click on the button “Retour au menu” to go back to “Exercises” and choose another activity.

- Answer key: when you have completed an exercise, a robot will appear at the bottom of the screen. Click on it to see the right answers. Misplaced elements will be shown in the correct places; the robot disappears ; and you can try the exercise again. Some

of the exercises (Sound Morphing, Musical Theme Morphing and Music Puzzle) have three levels, matched with three colors (blue, orange and pink). In these cases, each layer has its own correcting robot, which is color-coded.

Once back at "Exercises," check the small diodes over the doors. A red LED means that you finished this level of the exercise with no errors. If the LED is green, this means that when you quit the exercise there were still some mistakes remaining.

Classifying Sounds

Objective: to classify sounds by families, according to their timbres and their origins.

❖ Screen Display

(Level 1 display)

To the right of the screen is the sound pool. The same sounds, of various natures, are used in Levels 1 and 2. For Level 3, there are only instrumental sounds.

The left side of the screen displays the empty spaces reserved for the diverse families to be recognized. This side varies with the level of difficulty.

❖ Performing the Exercise

The point is to classify the sounds from the pool in the appropriate families:

Level 1	Level 2	Level 3
	Natural sounds	
Percussive sounds	Human sounds	Strings
	Instrumental sounds	
Woodwinds		
	Synthesized sounds	
Percussion		

	Natural Sounds	
	Human Sounds	
Strings		
Non-percussive sounds	Instrumental Sounds	Woodwinds
	Synthesized Sounds	
Percussion		

- In Level 1, the user must distinguish between percussive and non-percussive sounds. A percussive sound is principally characterized by a short attack. Conversely, a non-percussive sound has a slower attack.

- In Level 2, the classification is further refined. In addition to the two categories described previously, the user must determine whether the sound is **natural** (that is, sounds from nature), **human** (a human product), **instrumental** (produced by an acoustic musical instrument such as the violin or clarinet), or **synthesized** (produced by an electronic musical instrument or on a computer).

- In Level 3, instrumental sounds must be ascribed to their respective families, **strings, woodwinds and percussion**, while maintaining the distinction between percussive and non-percussive sounds.

Careful! "Percussive sound" does not necessarily mean the sound is produced by a percussion instrument. In effect, any musical instrument generally has several possible playing modes. Let's take the cymbal as our example. If you hit this instrument with a drumstick, you get a percussive sound. However, if you rub it with brushes, the resulting sound is non-percussive. Nonetheless, the cymbal is a member of the percussion family.

❖ Educator's Tips

Encourage the students to invent other possible categories of sound classification — *e.g.*, pleasant / unpleasant, long / short, sustained / non-sustained (refer to the exercise "Graphic Representations of Sound," under the heading "Going Further").

Graphic Representations of Sound

Objective: to match a sound with two forms of graphic representation: the amplitude envelope and the sonogram.

❖ Screen Display

(Level 1 screen)

On the left side of the screen is the pool of 10 sounds from various sources (including a baby's cry, a mosquito's flight, xylophone notes). Using the program AudioSculpt (Ircam) we've produced two graphic representations for each. They are located in two columns on the right of the screen.

- In the first (left-hand) column , each image represents an amplitude envelope, which can be related to the volume of the sound the ear perceives. The horizontal axis indicates time, the vertical axis shows volume.

- In the second (right-hand) column, each image represents a sonogram: with a sonogram, the frequency content of a sound can be visualized. The horizontal axis shows time, and the vertical axis reflects the frequency scale. The amplitude of each frequency is represented by color intensity — the deeper the color, the greater the amplitude; the lighter the color, the weaker the amplitude.

  Correspondingly, color at the bottom of the graph means that the sound contains low frequencies. Color at the top of the graph means that the sound has high frequencies.

❖ Performing the Exercise

In this exercise, the appropriate images are lined up with the corresponding sounds, by using the mouse. A good working technique is to enlarge each image and examine it while listening carefully to each sound from the sound pool.

❖ Educator's Tips

Ask the students to listen to the sounds, then draw them. Encourage them to represent each parameter (pitch, amplitude, length) separately, then to find a way to represent the timbre (for example, using colors).

❖ Going Further

In what follows, we will use examples taken from the exercise to clarify the concepts of the amplitude envelope and the sonogram.

Sound distribution by level of difficulty:

Level 1	Level 2	Level 3
Slide whistle 1	Sneeze	Spoons
Slide whistle 2	Bells	Harp
Xylophone	Nightingale	Techno drums
Xylophone+casseroles	Xylophone	Vibraphone
Baby's cry	Explosion	Washing machine
Drums	Yodel	Electronic Noise 1
3 Clarinet notes	Violin chords	Clarinet (normal)
Bird	Mosquito	Clarinet fluttertone
Child's laugh	Woman's voice	Electronic noise 2
Jew's harp	Clarinet glissando	River

The amplitude envelope

An amplitude envelope represents sound volume over time. On the first level of the exercise, enlarge this image of the amplitude envelope for the sound "Xylophone."

(Amplitude envelope for the sound "Xylophone")

What do you see?

You can count eight similar succeeding events. Each element is characteristic of a percussive sound. They appear at regular intervals on-screen.

This means that the events in the sequence follow one another in a regular rhythm. When we want to find the sound corresponding to this image, we need to look in the sound pool for a sequence of eight successive percussive sounds, evenly spaced**.** There is only one — the sound "Xylophone."

By analyzing this example, we can bring out two elementary ideas contained in the amplitude envelope: the idea of the sound event, and the idea of rhythm.

The shape of each event on the graph allows us to refine the analysis.

♦ Percussive and Non-Percussive Envelopes

A percussive sound is one whose attack is very short. A non-percussive sound, on the other hand, is characterized by its gradual attack. By observing the shape of the amplitude envelope, it's possible to identify the category a sound belongs to.

{Typical envelope for a percussive sound}

♦ The example above illustrates the case of a percussive, non-sustained sound. It's the sound of a xylophone key tapped by a mallet. The energy transmitted to the key by the mallet dissipates rapidly, hence the rapid decline of the amplitude envelope.

{Typical envelope for a non-percussive sound}

♦ Here we have the case of a sustained sound. It's the graphic representation of the sound "three clarinet notes." The musician's breath in the clarinet compensates for the loss of energy, "sustaining" the sound over time. The result is a longer amplitude envelope.

❖ Sonograms

Remember the data visible on a sonogram:

♦ the horizontal axis represents time;
♦ the vertical axis shows frequencies from 20 Hertz to 20,000 Hertz ;
♦ the amplitude : each frequency over time is symbolized by a color scale running from lightest to darkest. The absence of color at a given moment means that there is no frequency present in the sound at that instant.

The sonogram also conveys information already found in the amplitude envelope, *i.e.* , the number of sound events and the rhythm.

♦ Sonogram of a harmonic instrumental sound.

Let's look at the sonogram for a sequence of clarinet notes.

{Sonogram of the sound "3 clarinet notes'}

The graph shows a series of horizontal and parallel lines. This type of sonogram is termed harmonic. It is made up of what's called a fundamental frequency and other frequencies called harmonic.

The fundamental frequency corresponds to the lowest frequency. It gives the sound's pitch. The harmonics are multiples of this frequency, hence the regular placement of horizontal lines on the sonogram. The amplitude of each harmonic differs from one instrument to the next, allowing the ear to distinguish the sound of a violin from a clarinet. The amplitude of the fundamental and harmonic frequencies constitute one of the essential aspects of a sound's timbre.

In this example, the three clarinet notes emitted are lower and lower. The three notes are shown on the sonogram. We see clearly that the fundamental and the harmonics are reduced proportionally.

♦ Sonogram of a slide whistle

The slide whistle is a rudimentary instrument, made up of a whistle and a small tube stopped up at one end. By pushing or pulling on a lever connected to the stopper, the length of the tube changes. This modifies the sound pitch. Listen to the first sound of Level 1 of the exercise. You hear the sound of a whistle whose pitch diminishes over time (the tube length was increased).

{Sonogram of the sound "slide whistle 1"}

♦ What can we notice on the sonogram of the slide whistle?

The image is made up of a series of lines characteristic of instrumental notes – the fundamental and its harmonics. Over time these lines come closer together: in effect, the progressive decline of the fundamental causes the progressive diminution of the interval separating the harmonics. This sonogram clearly demonstrates the transition from a high note to a low note.

♦ Sonogram of percussion instruments

Here is the sonogram of a percussive sequence.

{Sonogram of the sound "drum"}

As a general rule, percussion instruments do not produce harmonic sounds (that is, sounds made up of a fundamental frequency and its multiples). If we strike the head of a snare drum with a drumstick (your hand will also do), we get what's called a noisy sound. This type of sound is made up of a large number of frequencies very close to one another, such that the ear can no longer distinguish an exact pitch in the sound.

This is why the sonogram of the drum sequence does not show evenly-spaced lines. Each of the percussive sounds in the sequence produces a sort of frequency cluster, with a massive vertical front reflecting the brevity of the attack.

Identifying Sound Events

Objective: to name the events in a sound sequence.

❖ **Screen Display**

Each sequence is made up of 12 sound events, produced by mixing one, two or three sounds, depending on the level of difficulty.

{screen for Level 2}

The icon for playing a sequence is found on the left side of the screen.

Above this button are 12 small lights which go on in succession as the sequence unfolds. They serve to localize the arrival of the 12 events.

Here the sequence is positioned on the seventh event

It's also possible to start playing a sequence from the numbered event of your choice, by double-clicking on the appropriate purple block to the left of the lights. Depending on the level of difficulty, one, two or three vertical lines extend from the lights. These lines are for placing the names.

- Here we're in Level 3. Event 9 comprises two sounds. Event 10 consists of three sounds. Event 11 has only one sound.

- On the right side of the screen is a list of names in alphabetical order. You cannot see all the names on-screen at the same time.

To access the whole list, position the mouse near the arrows and the list contents will scroll.

❖ Performing the Exercise

The user plays a sequence and then picks the corresponding name from the list of sound events.

Careful! There are more names than there are sounds to identify in the sound sequence.

If you're unsure or if you've made a mistake, you can put the names back in the list to the right. The order of the names from left to right does not matter. Only the order from top to bottom counts when answers are checked.

❖ Educator's Tips

Record a soundtrack in the street or elsewhere, then ask the students to identify each of the noises found on the recording (*e.g.*, a passing car, pedestrians, children screaming).

This exercise is readily adaptable for work with an entire class and one computer workstation. For example, while they listen to the tape, the students can use a sheet of paper with 12 boxes to fill in.

Sound Morphing

Objective: to take the stages of the transformation from one sound to another and put them in the correct order.

❖ Screen Display

A starting sound and an ending sound are placed on each line. We produced five stages in the transformation from one to the other, using AudioSculpt (Ircam): taken together this creates a sound "morphing." The idea is to arrange these steps in the right order. The screen is divided into three levels which work identically. Each level has two colored squares, which represent the initial sound and the final sound in the sound morphing. These icons frame the five empty spaces to position the remaining sounds.

Sounds already selected can be heard by pushing a button.

The sound pool, containing the transformation steps for each of the levels, is on screen-right.

❖ Performing the Exercise

The user aligns the transformation stages in the right order so as to reconstruct a continuous movement from the first sound to the last sound.

❖ Educator's Tips

Using AudioSculpt (Ircam), create other multiple-step sound morphs from the sounds the students have chosen.

More generally, you can also address the theme of sound transformation: use AudioSculpt with the students to make other sound transformations (such as inverted sounds, transpositions, filters).

Musical Theme Morphing

Objective: to reconstruct the movement from one musical theme to another.

❖ Screen Display

With the computer, transitions were effected between various musical themes from works by well-known composers. The number of steps for each transition varies with the level of difficulty.

{Level 1 screen}

The screen is divided into three levels which work identically. Each level contains two icons for playing the initial theme and the final theme. These icons frame five empty spaces where the user will put each of the remaining sounds.

Sounds already in place can be heard by selecting the button located above the spaces.

The sound pool, containing the various stages of the transition, is found on screen-right.

❖ Performing the Exercise

Listen carefully to each sound from the pool and position it so as to obtain a progressive transformation from one musical theme to the other.

The final theme (to the right) remains the same inside any given level. On the first level, there are five steps to get from one theme to the other. On the more advanced levels, the transition is achieved in six and seven steps respectively.

❖ Sequences

The chart below shows the distribution of musical excerpts by composer, in the corresponding levels of difficulty.

Level	Initial Theme	Final Theme
Level 1	Bach Boulez Baboni Schilingi	Beethoven
Level 2	Baboni Schilingi Beethoven Bach	Chopin
Level 3	Boulez Chopin Baboni Schilingi	Bach

The titles of the works selected, by composer (MIDI transcriptions), are as follows:

Johann Sebastian Bach (1685-1750)

- *Sonata in E Minor for violin and piano* (BWV 1023) – Level 1
- *Invention for Two Voices no.4 in D Minor* (BWV 775) – Level 2
- *Prelude in B flat Major* (BWV 560) – Level 3

Ludwig von Beethoven (1770-1827)

- *Sonata no. 17 in D Minor, op. 31 no. 2* (transposed in A Minor)

Frederic Chopin (1810-1849)

- *Etude no.1 in C Major, op.10*

Pierre Boulez (1925)

- *Structures pour deux piano, deuxième livre*

Jacopo Baboni Schilingi (1971)

- *Musique du Roi Beau*

❖ Educator's Tips

Starting with two well-known melodies, ask the students to write or to play on an instrument a hybrid melody created by combining them.

Music Puzzle

Objective: to reconstruct a sequence from its fragments. This is a kind of musical puzzle.

(Level 1 screen)

❖ Screen Display

The screen is divided into three levels, all functioning the same way.

The left side of the screen shows a button which allows for the whole sequence to be played.

The sequence is divided into seven fragments arranged to the right of the screen.

As the user classifies them, the sounds will be placed in the middle of the screen.

This button plays the elements already in position; the sequence is read from left to right.

❖ Performing the Exercise

The idea is to reconstruct the original sequence by positioning the fragments in the right order in the seven empty spaces in the middle of the screen.

The higher the level of difficulty, the longer the excertps and the more irregular the crosscuts.

❖ Sequences

For each of the three levels of difficulty, we have chosen three different types of sequences: first, an excerpt from a classical piano piece (in MIDI transcription); then an extract from a pop music piece; and finally, a sequence made up of sound effects.

♦ Level 1

- *Goldberg Variations*, BWV.988 — Johann Sebastian Bach (1685-1750); MIDI transcription.
- *Fast and Easy* — realized by Jean Lochard / Ircam
- *Ambiances naturelles* — realized by Jean Lochard / Ircam

♦ Level 2

- *Sonata for Two Pianos in D Major,* K.448 — Wolfgang Amadeus Mozart (1756-1791); MIDI transcription.
- *Baby-C* — realized by Jean Lochard / Ircam
- *Promenade* — realized by Jean Lochard / Ircam

♦ Level 3

- *Fantasy for Piano in F Minor, for four hands*, D 940 — Franz Peter Schubert (1797-1828); MIDI transcription.
- *Senza Virtuelle* — realized by Jean Lochard / Ircam
- *En voiture!* — realized by Cyrille Brissot / Ircam

❖ **Educator's Tips**

Since the musical fragments of this exercise are interchangeable, it's possible to reconstruct a piece different from the original. This game raises questions about the concepts of the musical phrase and the structure of a piece.

It's easy to create a music puzzle with a MIDI sequencer. Load a MIDI file (a piece of music the computer can read) into the program. Using the appropriate tool (often a pair of scissors), cut the piece into several fragments. Then have the students use these fragments in reconstructing the original piece or in building other melodies.

Acoustic Spaces

Objective: to recognize various computer-simulated acoustic spaces.

{Screen for Level 2}

❖ **Screen Display**

In this exercise, we used a program called Spat (Ircam), made for simulating different specific acoustic spaces. First we chose sounds recorded in neutral acoustics (that is, without reverberation), and then we simulated their propagation in several different acoustic spaces: bathroom, living room, concert hall, church.

The numberof acoustic spaces increases with the level of difficulty.

On-screen, each acoustic space is symbolized by a "streetlight;" their numbers vary from three to five depending on the level of difficulty.

♦ Distribution of acoustic spaces by difficulty level

Environment	Neutral	Bathroom	Living Room	Concert Hall	Church
Level 1	x	x		x	
Level 2	x	x	x	x	
Level 3	x	x	x	x	x

♦ By double-clicking on a "streetlight," you can listen to the base sound, as a point of reference, in order to get to know each auditory space. The first "streetlight" corresponds to a neutral sound, stripped of reverberation; the remainder of the streetlights go from the smallest room to the largest.

Careful! This does not mean the least reverberating to the most reverberating. Reverberation varies a lot depending on the material used to cover the walls of the acoustic space (see "Going further").

♦ On the right side of the screen is the sound pool, divided into four levels. Each one has a sound processed to reflect the acoustic spaces found in that level of difficulty.

❖ Performing the Exercise

You must listen to each sound, identify the acoustic space in which it's diffused, and then place it under the correct streetlight.

❖ Educator's Tips

Using a tape recorder and microphone, go with the students to record diverse sounds (percussion, voice) in various places (the entryway, the classroom, the courtyard). Have the students listen carefully in each of these places, their eyes shut, so as to "photograph" the sonic environment.

Once back in the classroom, try to identify each of the places you visited by listening to the sounds recorded in various environments and perhaps also by comparing them to sounds already played in the classroom for reference.

❖ Going Further

To produce the sounds for this exercise, we used the Spat program (Ircam), which, among other features, makes it possible to simulate very realistically the environment of a room whose characteristics the user selects. In the following paragraphs, you will find fuller explanations of propagating sounds in a given space.

♦ An overview of sound propagation

The origin of a sound is a physical phenomenon. A sound source (such as a violin or a speaker) creates a local disturbance in atmospheric pressure. This disturbance gradually spreads in the air, giving rise to a sound wave. Picture a stone thrown in the water for a useful image of the way a sound wave is propagated.

The ear perceives the acoustic wave and sends data to the brain, allowing us to identify the nature of the sound wave. The speed of a sound wave depends on the temperature, the pressure and the density of the surroundings in which it is diffused. In the air, the speed is between 320 and 340 meters per second.

♦ Sound trajectory between its source and the listener

When a sound source emits a sound, it is propagated in all directions in the space. This is called radiating. A listener only receives a fraction of the energy the source puts out, that portion which radiates in his or her direction.

♦ Reflection on a surface

When a sound wave strikes a surface, the angle of its reflection is equal to its angle of incidence, just like light on a mirror.

{A sound wave striking a wall: the incident angle (1) and the angle of reflection (2) are equal}

The wave suffers an energy loss which varies according to the material the wall is made of. The material is called "reflective" if the wave undergoes a small energy loss. It is "absorbent" if there's a marked energy loss. In this case, the reflected wave is practically nonexistent.

♦ Sound diffusion in a room

There are numerous phenomena of sound wave propagation and reflection in any given room.

Let's take the example of a theater, and examine the sound's trajectory between a musician playing onstage and a listener seated in the hall.

----> direct sound
----> early reflections
----> example of multiple reflections

{Sound's trajectory in a theater: the direct sound, some early reflections and a radiant undergoing multiple reflections are pictured.}

The musician plays an instrument:

- The listener first perceives the direct sound coming from the instrument. The direct sound is the one which takes the shortest path between the musician and the audience member.
- The listener then perceives the sound waves coming from the reflections against the walls.

♦ Impulse Response

To identify the features of a concert hall, the response to an impulse signal is studied. This consists of sending a very short signal (often a pistol shot) from the stage, and recording the received signal at various specific points in the hall.

♦ Graphic representation of an impulse response

{Chart> Intensity. Time (1)Direct sound (2) Early reflections (3)Multiple reflections against the walls}

When **t=0**, a short sound is transmitted from the stage.

Direct sound is received at time **t1**, a function of the sound's speed in the hall and of the distance separating the sound source from the listener.

Thereafter, a series of signals reaches the audience member starting at time **t2**: these are the early reflections. They correspond to the radiants with only one reflection against the walls. Their length (**t2 - t1**), the time between direct sound reception and reception of early reflections, is the principal parameter allowing the listener to grasp the size of a space. Effectively, the more voluminous the hall, the greater the length.

The third part of the signal received starting from time **t3** is more confused. It's made up of radiants having undergone several successive reflections against the walls. These late reflections are received in such short lapses of time that the ear is no longer able to distinguish one from the next.

The sum of all these reflections constitutes the reverberation, which depends on the hall's volume and on the materials used in covering the walls.

To describe hall acoustics, we often speak of the Time of Reverberation (**TR**). This is the length between the emission of a brief sound in the hall and its quasi-complete extinction.

- **Simulating an acoustic space**

Computers are now powerful enough to simulate artifical acoustic spaces very realistically. They are capable of reproducing a sound's multiple reflections against the walls by using delay lines.

In practice, in order to use Spat to reproduce the acoustics of a hall or other space, the computer must first have a recording of the hall's impulse response. The recording is analyzed by a program which furnishes the principal parameters for simulating the reverberation (pre-reception length of the early reflections, time of reverberation). Then the simulation is refined by ear, by comparing the artificial reverberation with the original impulse response and modifying the Spat's internal parameters.

- **Time of Reverberation (TR) of the environments of this exercise**

Environment	TR in seconds
Neutral environment	-0-
Bathroom (*)	1.445
Living room	0.550
Concert hall	2.187
Church	4.365

(*) A bathroom, whose wall are tiled, reverberates more than a living room, despite its smaller size.

Locating a Sound Source

Objective: to locate the origin of a sound source.

❖ Screen Display

At screen-right you will find a pool of sounds spatialized with Spat (Ircam), which allows you to control the position of sounds in a simulated acoustic space. We have selected four different localizations. This way, a listener with headphones can hear a sound source placed to the left, to the right, in front, or behind.

These four localizations are represented onscreen. They are arranged around a head as seen from above.

❖ Performing the Exercise

First, determine where the sounds in the pool are situated, then put them in the right places with respect to the head.

Careful! For this exercise, you must use headphones. Make sure that you're wearing the headphones correctly! (L over the left ear, R over the right ear)

❖ Educator's Tips

Blindfold one student at a time, who will identify the location of a sound source and then track its movements as precisely as possible (refer to the following exercise). Have the other students produce the sounds.

Sound Sources in Motion

Objective: to identify the movements of two sound sources mixed into a single sequence.

❖ **Screen Display**

Using Spat (Ircam) to control sound movement in a simulated acoustic space, various sound sequences were processed. Each has two sounds in motion and can be classified in six categories combining elementary directions: in front, behind, left, right – all with the listener as reference point.

Careful! This exercise can be performed with a pair of speakers, but perceiving the movement of the sound sources is easier with headphones (be sure to place the earpiece L over the left ear, R over the right).

❖ **Performing the Exercise**

The idea is to classify the sequences by the sounds' movements, as represented by the following icons:

♦ Front-Back Movements

- the two sounds move apart toward the rear
- the two sounds cross*
- the two sounds draw closer together toward the front

♦ Right-Left Movements

- both sounds move toward the left
- the two sounds cross*
- both sounds move toward the right

*Movements starred with an asterisk are not found in Level 1 of the exercise. The sequences to be sorted are arranged screen-right.

Synchronizing Sound and Image

Objective: to find adequate synchronization between an image and a sound.

❖ **Screen Display**

This exercise offers five episodes of Charles Perrault's *Little Red Riding Hood*, loosely interpreted. We created three sound

sequences variously synchronizing image and sound for each episode. All of these sequences are positioned on the right side of the screen. Double-click on a given sequence to play it, framed center-screen.

❖ Performing the Exercise

There is only one correct solution for synchronizing each episode of the story with its corresponding sound sequence. This is the sequence that must be brought into the frame located to the left of the screen.

At the end of the exercise, a button lights up. Double-click on this button to see the whole story.

❖ Educator's Tips

There are programs on the market that make it easy to create short animations, combining images with sound, easily.

Prepare a brief video sequence and a sound palette ahead of time. Ask the students to develop diverse sound illustrations by playing with sound-image sychronizations.

Installing the CD-ROM

Macintosh Installation

Minimum system requirements:

Mac PowerPC 200 MHz
System 8.1
14" screen thousands of colors
8x CD-ROM drive or faster
32 Mbytes RAM (8 Mbytes free)
QuickTime 3 or higher

Installing the CD-ROM:

Turn on your computer and insert the CD-ROM into the drive. Double-click on the "10 jeux d'écoute" icon that appears on the desktop. A window will open with various files:

- "Lisez-moi" ("Read me"): this has last-minute information; read this before proceeding any further.

- "Démarrage" ("Getting started"): this launches the application.

*Careful! — The **10 Listening Games** CD-ROM requires prior installation of QuickTime 3 (or higher) on your computer!*

If you do not have QuickTime (delivered with Mac OS 8.5), you can use the installer provided on the CD-ROM. Or you can download the latest version for free from the Apple site at the following address:

http://www.apple.com/fr/quicktime/

With QuickTime, your system can read digital sounds and videos.

PC Installation

Minimum system requirements:

Pentium PC 200 MHz
Windows 95 or higher
14" screen thousands of colors
8x CD-ROM drive or faster
32 Mbytes RAM
QuickTime 3 or higher
16-bit sound card, SoundBlaster compatible

CD-ROM installation

After opening Windows 95/98, insert the CD-ROM *10 Listening Games* into the drive.

Open the workstation. Click on the CD-ROM icon. A new window will open with these files:

- “Lisez-moi” ("Read me"): this has last-minute information; read this before proceeding any further.

- “Démarrage” ("Getting started"): this launches the application.

*Careful! — The **10 Listening Games** CD-ROM requires prior installation of QuickTime 3 (or higher) on your computer!*

If you do not have QuickTime, you should copy the installation program from the CD-ROM onto your hard drive, then launch it. Or you can download the latest version for free from the Apple site at the following address:

http://www.apple.com/fr/quicktime/

QuickTime lets your system read digital sounds and videos.

10 LISTENING GAMES

Ateliers Ircam

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For students, activity leaders and teachers in the music sector, Ircam offers educational workshops thematizing ideas explored in this CD-ROM, as well as other topics in music and new technologies.

For more information, please call (33) 01 44 78 48 17 or 01 44 78 48 23.

♦ MANUAL
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